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(71) Applicant (*for all designated States except US*): PROQUIP SPECIAL PROJECTS LIMITED [GB/GB]; U.4 Church Road Industrial Estate, Lowfield Heath, Gatwick, East Sussex RH11 0PW (GB).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): RICKMAN, Cliff [GB/GB]; Proquip Special Projects Limited, U.4 Church Road Industrial Estate, Lowfield Heath, Gatwick, East Sussex RH11 0PW (GB). BAKER, Ross [GB/GB]; Proquip Special Projects Limited, U.4 Church Road Industrial Estate, Lowfield Heath, Gatwick, East Sussex RH11 0PW (GB).

(74) Agents: EVANS, David, Charles et al.; fJ Cleveland, 40–43 Chancery Lane, London WC2A 1JQ (GB).

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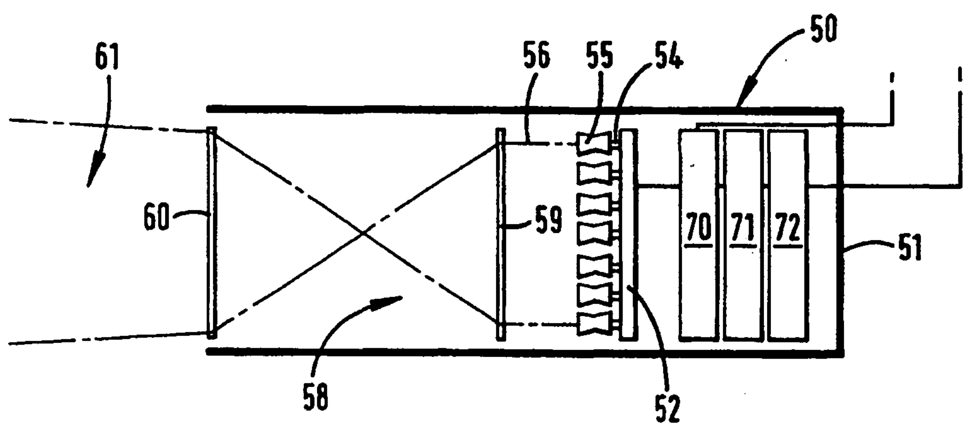

(57) Abstract

This invention relates to lamps and has particular reference to lamps comprising clusters of light emitting diodes. According to the present invention there is provided a light source comprising an LED array, including at least two types of LED having different light emitting characteristics, each LED being associated with light collimating means to concentrate the light output from each LED substantially parallel to an optical axis for the device, and a focusing optic assembly with means for varying the distance between the LED array and at least part of the optic assembly, thereby permitting control or focusing of the light output from the array to control the resultant beam of light emanating from said source.

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LED Lamp

This invention relates to lamps and has particular reference to lamps comprising clusters of light emitting diodes.

A light emitting diode (LED) is a solid state device which operates at low voltages. A diode is essentially a two terminal device which conducts electricity in one direction only. If an alternating current is fed to it, it rectifies the current to DC by only passing half the current flowing in one direction. The semi-conductor diode is well-known and can be made in many versions depending on the particular material from which the diode is made. Essentially, pure silicon is doped with other elements and different types of semi-conductor known as P-type and N-type can be put together to form a P-N junction which creates the semi-conductor diode. The effect of the junction is to allow electricity to pass in one direction but not in the other. By selecting the material for the "doping", the electron energy inherent in the device can result in the emission of electro-magnetic radiation, and in the release of photons or quanta of electro-magnetic radiation. The doping material will determine the nature and wavelength of any

resultant electro-magnetic radiation. For example, pure gallium arsenide will result in an output in the invisible infra red range, while silicon carbide and gallium-indium mitride will tend to produce radiation output in the visible blue light region of the spectrum.

Until recently, spectrally pure LED's with high efficiency have been an expensive product and to produce relatively high light output involves highly complex layered junction structures with complex electronics to produce radiated frequencies which beat together to produce the required visible wavelength.

It will be appreciated that in order to produce a full colour display, it is essential that the primary colours of red, green and blue are available to allow the creation of the complete colour range.

With the advent of high output LED's such as those currently produced by Toyoda Gosei Co Ltd it is now possible to produce high output LED cluster lamps. The initial use for these devices would normally be within vehicles and like uses where a combination of robustness and low power consumption has considerable attraction.

The output of an LED is, however, very diffuse and attempts to use LED cluster arrays suffer from the disadvantage that the diffuse light is very much in the nature of an area floodlight. The use of normal focusing optics to produce a greater concentration of light does result in some concentration of light, but there is nevertheless an overall lack of efficiency, since much of the light is not picked up by the optical system and is, therefore, wasted. Unlike traditional light sources which are relatively small, and LED array covers, a considerable surface area and the optic arrays currently available are unable to control such as area light source.

Furthermore, attempts to produce LED cluster lights have resulted in the production of lights requiring separate power supplies and pulsing systems. In order to operate, an LED must be continually pulsed in order to produce pulses or quanta of light as each pulse is passed across the junction. The apparent continuous illumination is the result of rapid pulsing at very high frequency typically 1200 hz.

The applicants have found that by manufacturing an array of LED's they can incorporate this together with

the necessary power supply and control interface to provide lighting source with an output substantially equivalent to an incandescent or arc lamp but utilising approximately 1/5 of the energy consumption. The result is that much less heat is generated and the devices are easier to work with in a stage environment.

According to the present invention, therefore, there is provided a light source comprising an LED array, including at least two types of LED having different light emitting characteristics, each LED being associated with light collimating means to concentrate the light output from each LED substantially parallel to an optical axis for the device, and a focusing optic assembly with means for varying the distance between the LED array and at least part of the optic assembly, thereby permitting control or focusing of the light output from the array to control the resultant beam of light emanating from said source.

In another aspect of the present invention, there is provided a light source comprising

an LED array, including at least two types of LED having different light emitting characteristics, each LED

being associated with light

collimating means associated with each LED to concentrate the light output from each LED within a narrow angle to the optical axis of the device, and

characterised by control interface means including dimmer means for selectively dimming some or all of the LED's in the array, thereby permitting variation of the colour output of the light source.

In one aspect of the present invention the components may be incorporated in a housing together with independent power supply means and a control interface. The control interface may include dimmer means for selectively dimming some or all of the LED's in the array, thereby permitting variation of the colour output of the light source. The control interface may also include means for controlling the relative movement between the LED array and the optic assembly.

In one aspect of the invention the LED array is fixed and the optic assembly is, at least in part, moveable to allow for focusing the emitted light beam from the device.

Typical light emitting diodes are those manufactured by Toyoda Gosei Co Ltd under their reference E1L and E1S.

The array may comprise rows or clusters of red, blue and green LED's and control means may be provided for changing the illumination level of some LED's within the array, enhancing the illumination of others, thus changing the colour and/or colour balance of the resulting illumination.

In an alternative embodiment, control means may include separate control for all the LED's of a given type, thus permitting control of the colour output without substantially changing the colour balance. This permits 100% dimming control without colour temperature change, i.e. the lamp can be faded from full brightness of any colour down to zero output with virtually no change in colour temperature.

Existing lamps either change colour as they dim or become unstable at levels below substantially 100% light output.

The lamps in accordance with the invention maybe manufactured largely of a plastics material. They are

extremely efficient and the lamp consumes under 20% of the power required for equivalent illumination from prior art devices. This relatively low heat output permits the lamp housing and composite optics of the LED's to be constructed of a plastics, or a lightweight composite material. The LED's can be embedded in a matrix rendering the whole structure extremely rugged. There is no filament to fail or glass to break, and lifetimes of 50-100,000 hours to half brightness is typical compared with approximately 1000 hours life for a standard type high-efficiency tungsten lamp.

With the advent of the computer control of lighting systems in stage management, the ability to control each individual coloured LED over a range of 250 brightness levels (8 bits) tends to give a total control range of 256^{3}, that is to say approximately 16 million colours.

Devices in accordance with the present invention permit the use of USITT standard for the control of theatre lamps, namely DMX 512,1990. This communications protocol allows 512 channels of control from a single twisted pair cable. The use of 4 channels of control, one each for red, green and blue and a fourth for overall brightness leaves other channels available for the use

of ancillary devices such as gobo wheel, zooming, focusing, pan, tilt etc.

In another aspect of the invention direct computer control may be employed to control the 1931 CIE Chromicity Triangle for the precise matching of colour output.

In another aspect of the invention, the control means is fully programmable as to the illumination characteristics of each of the LED types in the array thus permitting precision control of the colour output.

In one aspest of the invention, a colour data base may be provided together with look up means thereby permitting reproduction of the illumination parameters of the LED array to produce a predetermined colour.

This approach may be developed further to produce improved resolution of colour gradation across an array thus resulting in improved effective resolution of the light output in a way which takes account of the non linear characteristics of the eye.

The individual colours in the gradation may be

determined and programmed in the control means for the LED array, together with coordinates for the position of the required colour in the array. In operation, the control means address a look up database for the array to determine the illumination for the pixel group corresponding to those coordinates. In this way, it is possible for one lamp to produce illumination with changes in colour from one part to another. Thus, illumination is possible in stripes of different colours ie red, white and blue, or in concentric circles or in any other combination of patterns.

Thus a single lamp array may provide a variety of different and if necessary independent effects over an area to be illuminated.

Lamps produced in accordance with the present invention have an additional advantage of reducing rigging and installation time as the lamp only need be positioned and the power cable plugged in. The data materials can be fed through a standard lighting control desk using the main power supply leads for this purpose. The addressing control of each lamp could be adjusted by providing suitable control means, the input of which may be selected by means of a small thumb wheel switch on

each lamp.

Following is a description by way of example only with reference to the accompanying informal drawings, of methods of carrying the invention into effect. In the drawings:-

Figure 1 is a front view of an LED array for use in a lamp in accordance with the present invention.

Figure 2 is a side view of the array of Figure 1 showing the mounting of the LED's and their termination at the back of the array.

Figure 3 is a perspective view of a small lamp in accordance with the present invention.

Figure 4 is a view of a control circuit for use in conjunction with the array and lamp of Figures 1 to 3.

Figure 5 is a perspective view of the transformer and the power amplification stages for each primary colour LED's.

Figure 6 is a section through a unitary LED lamp in

accordance with the present invention.

Figure 7 is a circuit diagram for the pulsing and control circuit of the lamp and control systems of Figures 1 to 5 and the lamp assembly of Figure 6.

The LED array indicated generally at (10) comprises a diagonal row of blue LED's (11), a diagonal row of red LED's (12), a diagonal row of green LED's (13). The colour sequences are repeated in row banks (15) and (16) etc across the array. In a production model it is desirable that the LED's are mounted as close to each other as possible.

In the embodiment shown in Figure 2 each LED is mounted on a backboard (18) and groups of LED's are provided with control resistors (19), the output terminals (20) of which extend through a second board (21) located in substantially spaced parallel relationship with board (18).

The board (18) and its associated backboard (21) are essentially rectangular in shape and are surrounded on the side of the LED's with a forwardly projecting housing (22) (see Figure 3). The input to each group of

individual colour LED's ie all the green, all the red and all the blue LED's are each connected to a single input for that colour.

Mains power supply (30) (see Figure 7) is transformed down to 12 volts by means of transformer (31). In principle the output from the transformer (31) feeds a quad op amplifier for driving each bank of colour LED's. Three outputs are provided, each controlled by a variable resistor (33). The output from each variable resistor passes to a power amplification stage which then powers each LED array.

Turning now to Figure 7 in detail the circuit components are as follows:-

All values stated (where applicable) and type numbers noted on circuit diagram.

XXX is a non specific mains input connector.
XFMR1 mains input transformer, takes AC supply down to working voltage of approximately 9-12 volts.

D3, D4. are power diodes, for rectify incoming AC.

R1 is a pull-down resistor for IC1a input.

IC1a is one quarter of a quad op amp., which unparts a cosine-like waveform reference to IC1b,c,d.

C1 is an RC timing circuit with R2, via diode D1.

D1 isolates the RC timing circuit from supply: this stops C1 being discharged through the low impedance of components attached to the power supply rails.

R2 forms an RC timing circuit with C1, modifying the amplification (by IC1a) of the incoming un-smoothed DC to give a cosine-like waveform at the output of IC1a.

D2 isolates the DC supply to smoothing capacitor C2.

C2 smooches the DD for supply via VR1,2,3, to the non-inverting inputs of IC1b,c,d.

R3 forms the bottom third of a voltage dividing network with R4 and R5 to supply a bias voltage to the inverting input to IC1a.

R4 forms the middle third of a voltage dividing

network with R3 and R5 to supply a mid supply voltage to the non-inverting inputs of IC1b,c,d, via VR1,2,3.

R5 forms the top third of a voltage dividing network with R3 and R5 to supply the D to the whole of the quad op amp, IC1. Connection not shown on diagram, as IC power supplies are assumed.

R6 is a current limiting resistor. Limits output current of op amp to prevent damage to the base of the following transistor. R6 is identical in value and function to R10 and R14.

R7 forms voltage dividing network with R8, and limits drive current to the base of the output drive transistor.
R7 is identical in value and function to R11 and R15.

R8 is a pull-down resistor for the base of the output driver transistor and is identical in value and function to R12 and R16.

R9 limits the current through the series connected LED's. Identical in value and function to R13 and R17.

TR1 (identical in type and function to TR3 and TR5) inverts the active low signal from the outputs of op amps IC1b,c,d, to give a positive going voltage to operate TR2.

TR2 is a power transistor switching the current directly through the series connected LED's and is identical in type number and function to TR4 and TR6.

LED1-LED3. Red Light Emitting Diodes.

LED4-LED6. Green Light Emitting Diodes.

LED7-LED9. Blue Light Emitting Diodes.

The first operational amplifier in the circuit (ICIa) operates as a non-linear waveform generator. This op amp takes the full wave rectified (but un-smoothed) direct current signal and modifies it to output a non-linear waveform, resetting to zero at every zero crossing point of the AC cycle. This waveform is then simultaneously fed to the inverting input of three identical operational amplifiers, IC1b,c,d, each wired as comparators. A smoothed D voltage is then fed to the non-inverting input of IC1 b,c,d, via variable resistors

VR1,2,3. The non-linear waveform is thus compared with the D voltage. If the D voltage applied to the op amp is low, then the comparison point where both voltages are equal is meet very soon after the zero point of the AC cycle. The output stage of the op amp thus drives the lamp for a large proportion of a half cycle of the AC supply and the lamp will be bright as it is turned on for a proportionately long time. If the variable resistor is adjusted to give a high voltage to the op amp input, then the lamp remains off for a longer time, waiting for the reference signal to rise until the comparison point is reached. This allows a shorter time for the op amp to drive the lamp before the next zero point of the AC waveform is reached. Thus the lamp will be dimmer. The output of the op amps feed each feed a transistor which inverts the signal to drive the NPN power transistors. One drive transistor is used per colour for each of the colours red, green and blue.

For a larger lamp containing large numbers of LED's several transistors may be used per colour to spread the load. For the sake of simplicity, only a single power transistor per colour is shown. The power transistor allows current to flow through several LED's in series (three shown here), their power being supplied by the un-

smoothed AC supply. More than one LED is used in series as a form of circuit protection. Were the power supply to be of a lower voltage and only many paralleled single LED's to be used, an LED could short-circuit and thus render all the other parallel LED's inoperative.

Using the array and lamp described with reference to Figures 1 and 3, a variable light output was obtainable over the whole colour range without substantial change in colour temperature.

In an alternative embodiment of the present invention shown in Figure 6 a substantially rectangular lamp case (50) is closed at its rearwood end (51)and intermediate its length is provided with an LED cluster board (52) having an array of LED's mounted thereon in the manner described with reference to Figures 1 to 3. Each LED (54) is provided a collimating optical element (55) which serves to collimate the light output from LED (54) to a substantially linear beam (56), substantially parallel to the optical axis of the device.

The forward part of the housing (50) accommodates an optical assembly indicated generally at (58). In this particular embodiment a rearwood optic (59) is moveable

along the optical axis of the lamp while a forward optical assembly indicated generally at (60) is fixed. The arrangement is such that movement of the optical element (59) permits focusing of the resultant light beam (61).

The optical requirements of a lamp in accordance with the present invention differs significantly from those of the traditional arc or incandescent lamp. Instead of a substantially point or bar source of light, the LED light source is a planar array of light and the collimating and focusing requirements are, therefore, substantially different.

The rearwood portion of the housing is adapted to accommodate a power supply (70), dimming means (71) and a digital control interface (72). The digital control interface may either be provided with its own separate data input or may be adapted to receive data supplied by the power input.

The lamp in accordance with the present described above, and in accordance the present invention, may have a light output equivalent to that of a 650 watt tungsten spotlamp. The total power consumption for the equivalent

amount of light would be of the order of 90-100 watts and the heat output from the device is correspondingly reduced.

Claims

1 A light source comprising

an LED array, including at least two types of LED having different light emitting characteristics, each LED being associated with light

collimating means associated with each LED to concentrate the light output from each LED within a narrow angle to the optical axis of the device, and

characterised by control interface means including dimmer means for selectively dimming some or all of the LED's in the array, thereby permitting variation of the colour output of the light source.

2 A light source as claimed in claim 1 characterised in that the narrow angle of the light output from each LED is within the range of 2° to 5°.

3 A light source as claimed in claim 1 or claim 2 characterised in that the collimating means is formed integral with the LED to provide a narrow angle of light output within the range of 2° to 5°.

4 A light source as claimed in any preceding claim characterised in that focusing optic assembly means including means for varying the distance between the LED array and at least part of the optic assembly, thereby permitting control or focusing of the light output from the array to control the resultant beam of light emanating from said source.

5 A light source as claimed in claim 4 characterised in that the control interface means includes means for controlling the relative movement between the LED array and the optic assembly.

6 A light source as claimed in any preceding claims characterised in that the array comprises rows or clusters of red, blue and green LED's and the control interface means acts to change the illumination level of some LED's within the array, by reducing the level of the illumination of some LED's and enhancing the illumination of others, thus permitting changes in the colour and/or colour balance of the resulting illumination.

7 A light source as claimed in any one of claims 1 to 5, characterised in that the control interface

means includes separate control for all the LED's of a given colour, thus permitting control of the colour output without substantially changing the colour balance thereby providing 100% dimming control without colour temperature change.

8 A light source as claimed in any preceding claim characterised in that LED array is embedded in a matrix structure.

9 A light source as claimed in any preceding claim characterised in that the control means includes the USITT standard DMX 512,1990 for the control of theatre lamps.

10 A light source as claimed in claim 9 characterised in that the control means further comprises communications protocol allows 512 channels of control from a single twisted pair cable.

11 A light source as claimed in claim 9 or claim 10 characterised in that the control means further comprises means for using 4 channels of control, one each for red, green and blue and a fourth for control of brightness thereby leaving other channels available

for the use of ancillary devices.

12 A light source as claimed in any preceding claim characterised in that the control means includes means for controlling the 1931 CIE Chromicity Triangle for the precise matching of colour output.

13 A light source as claimed in any preceding claim characterised in that the control means includes addressing control means for each lamp and adjustment means for the input, which adjustment means comprises a small thumb wheel switch.

14 A light source as claimed in claim 13 characterised in that said adjustment means comprises a small thumb wheel switch on each lamp.

15 A light source, as claimed in claim 1 and substantially as herein described with reference to and as illustrated in the accompanying drawings.

FIG. 1

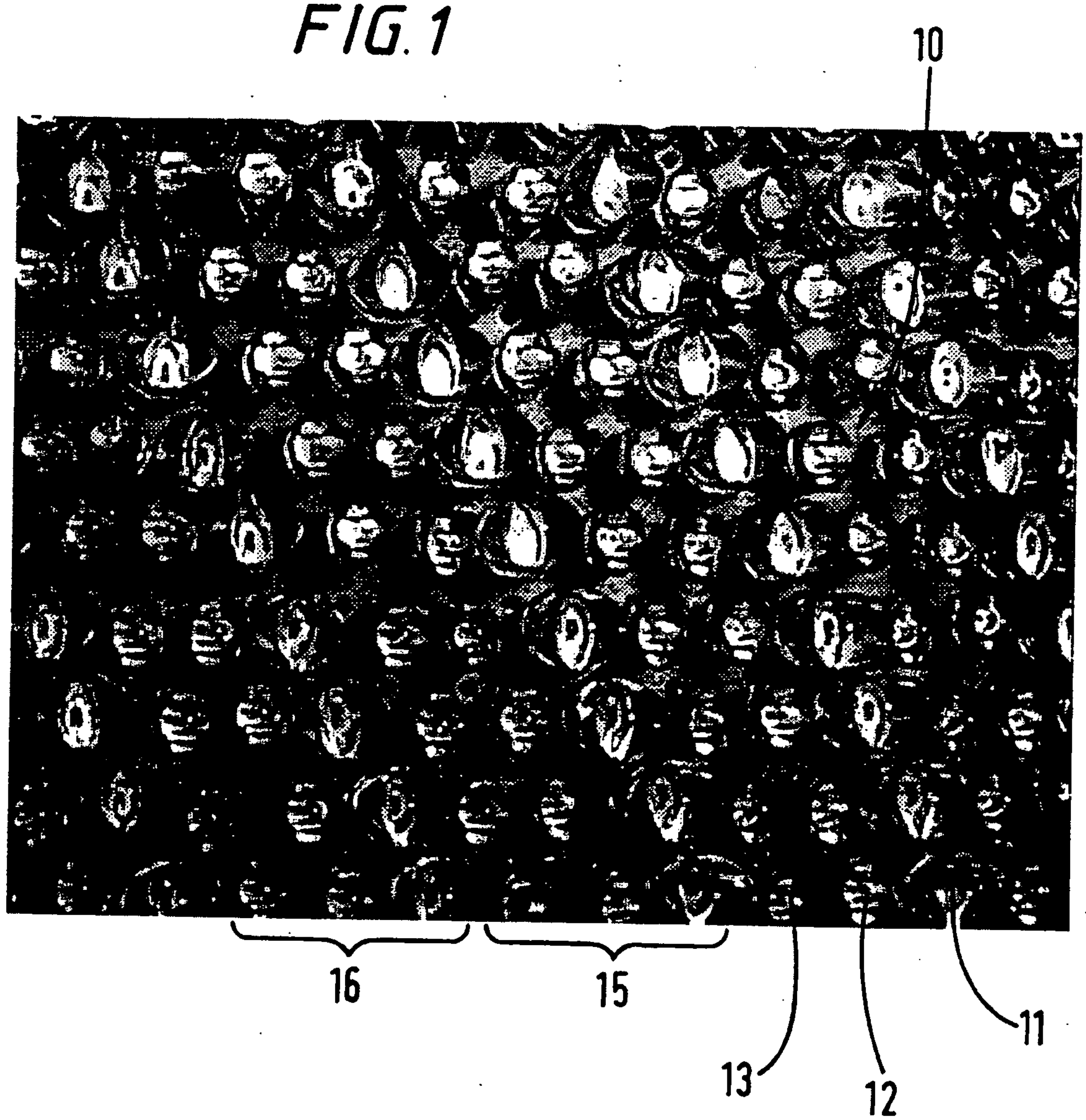
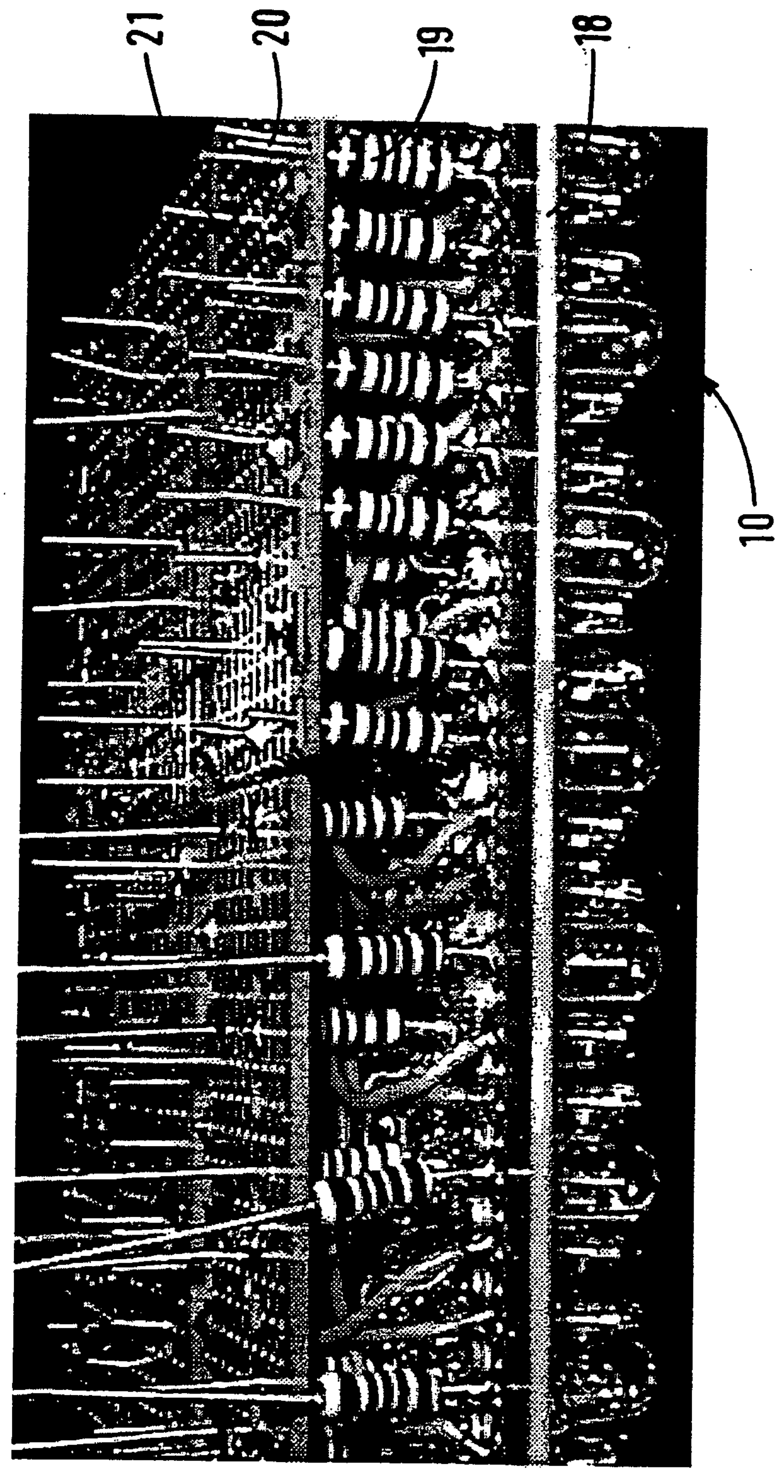


FIG. 2



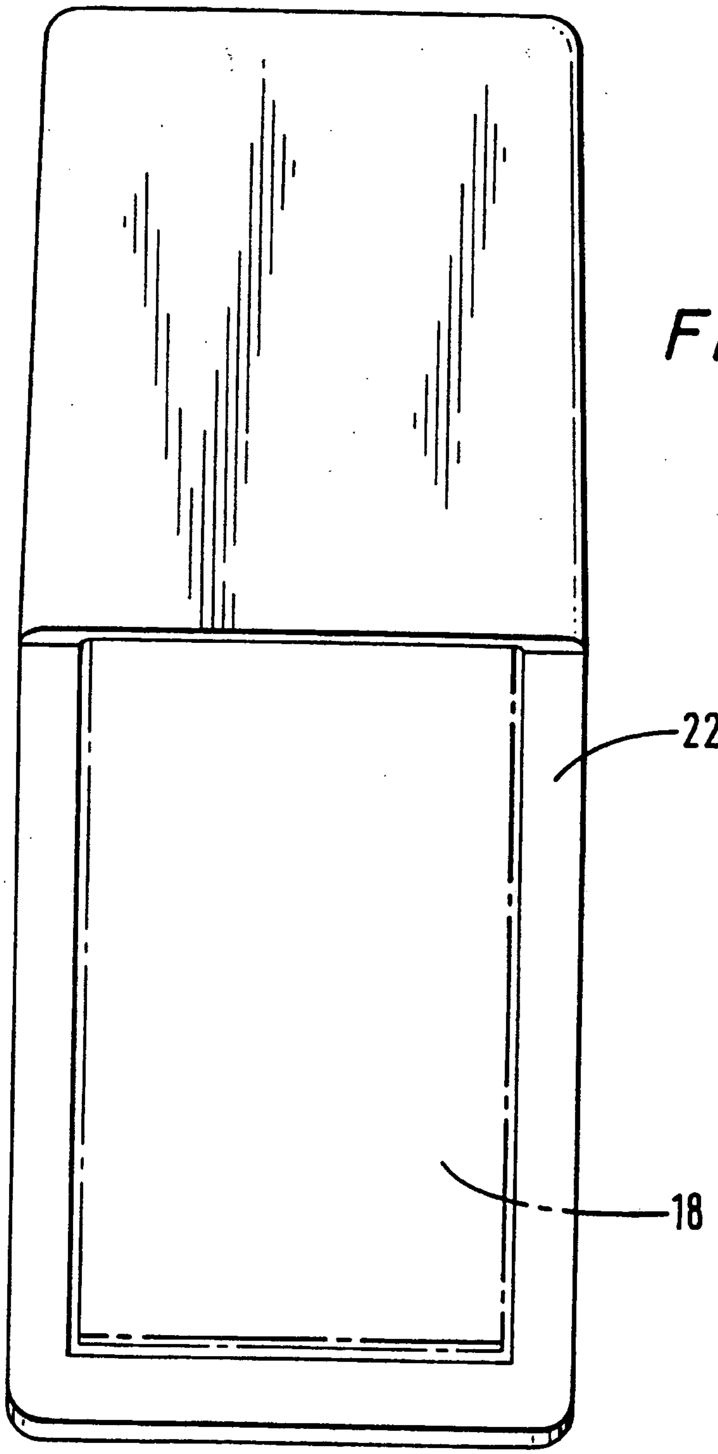


FIG. 3

FIG. 4

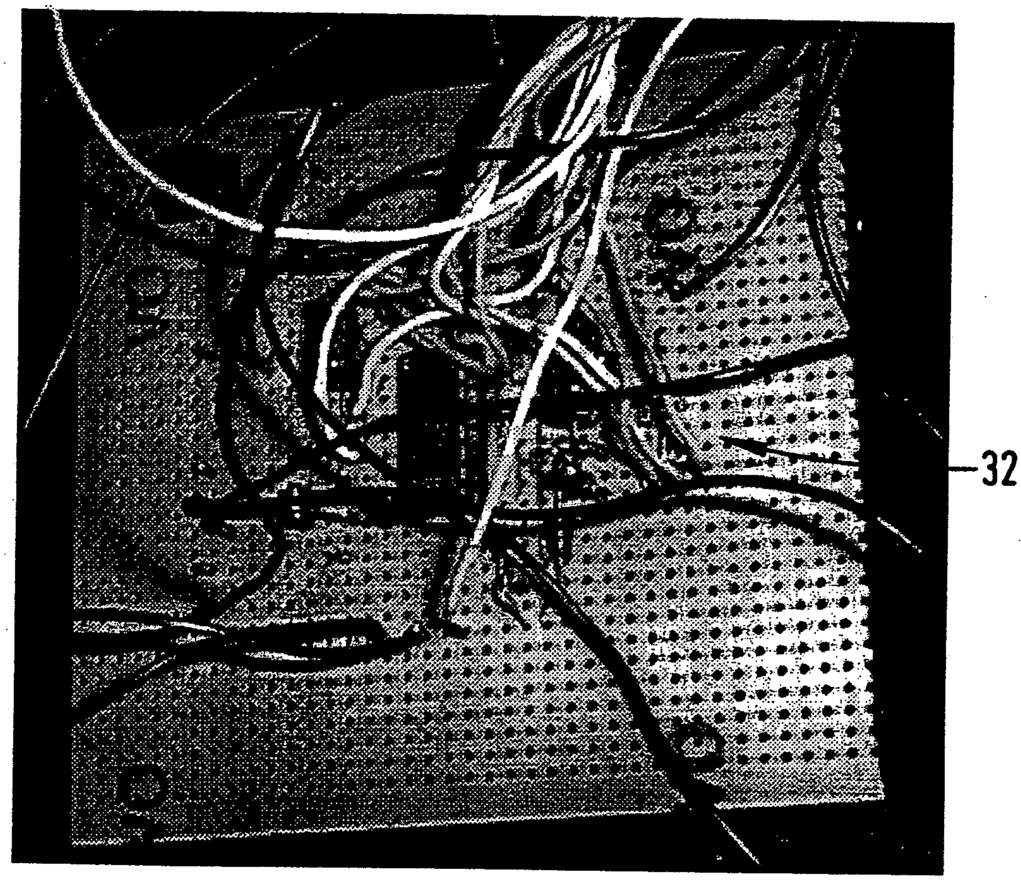
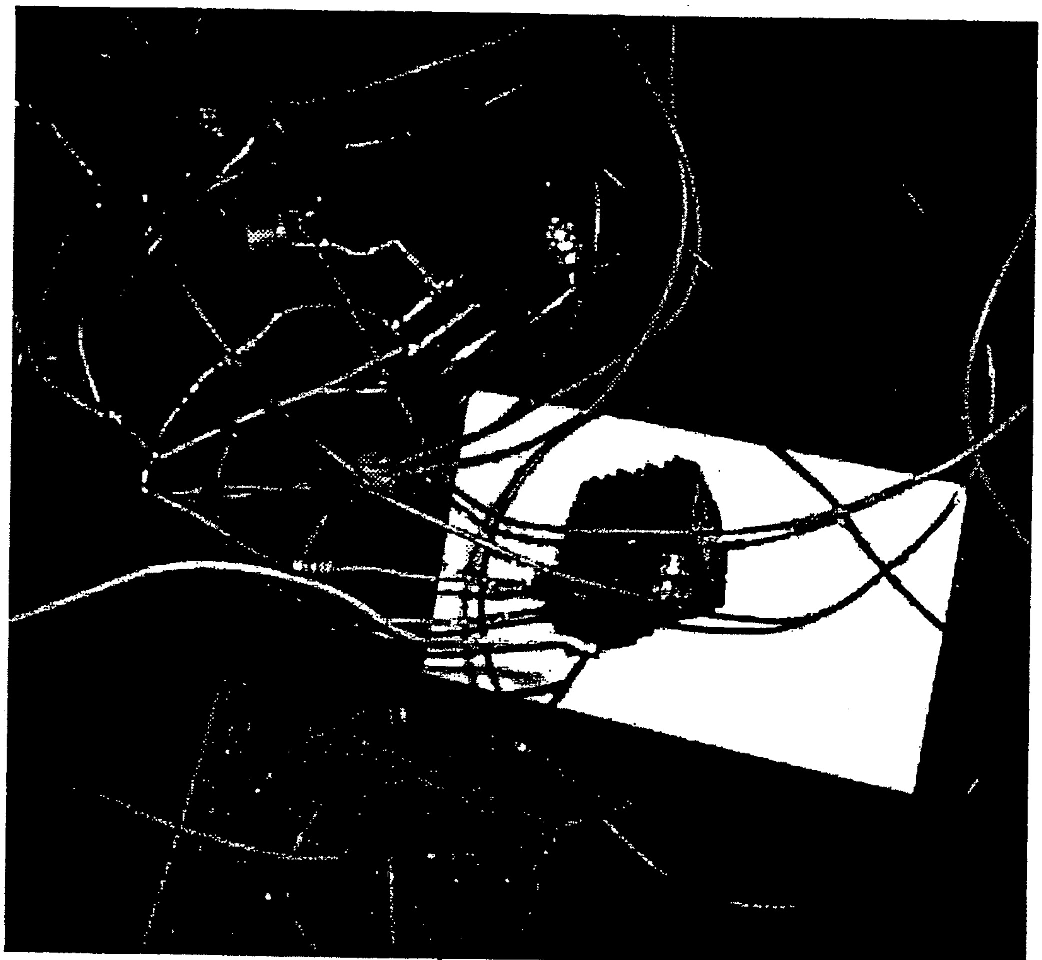


FIG.5



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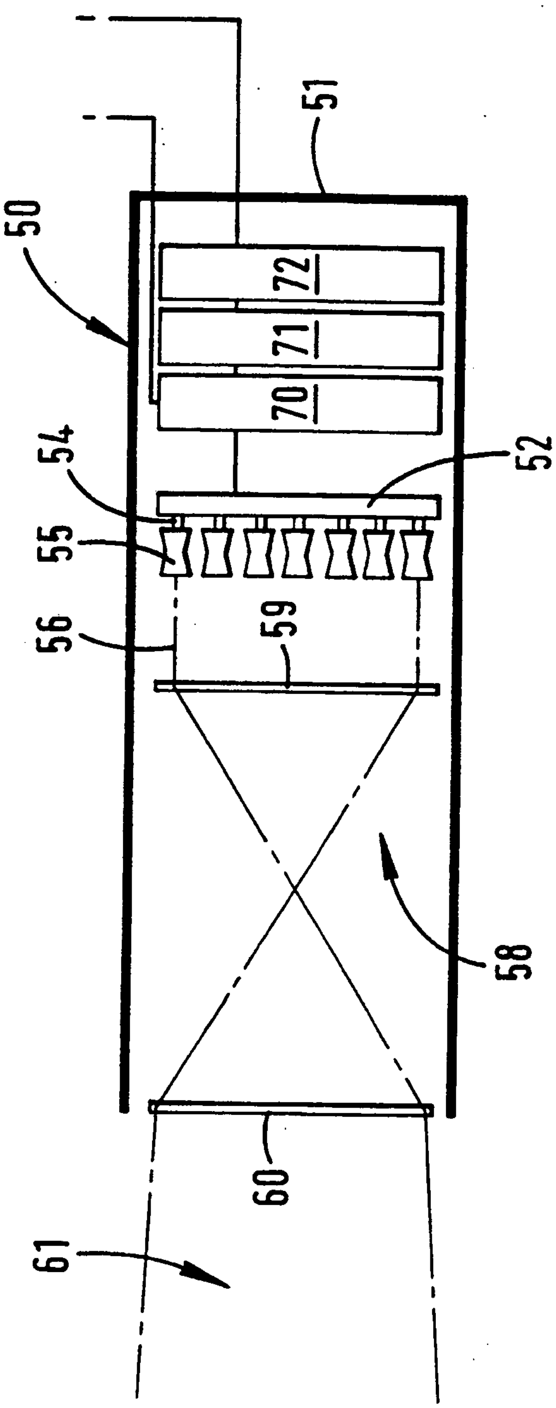

FIG. 6

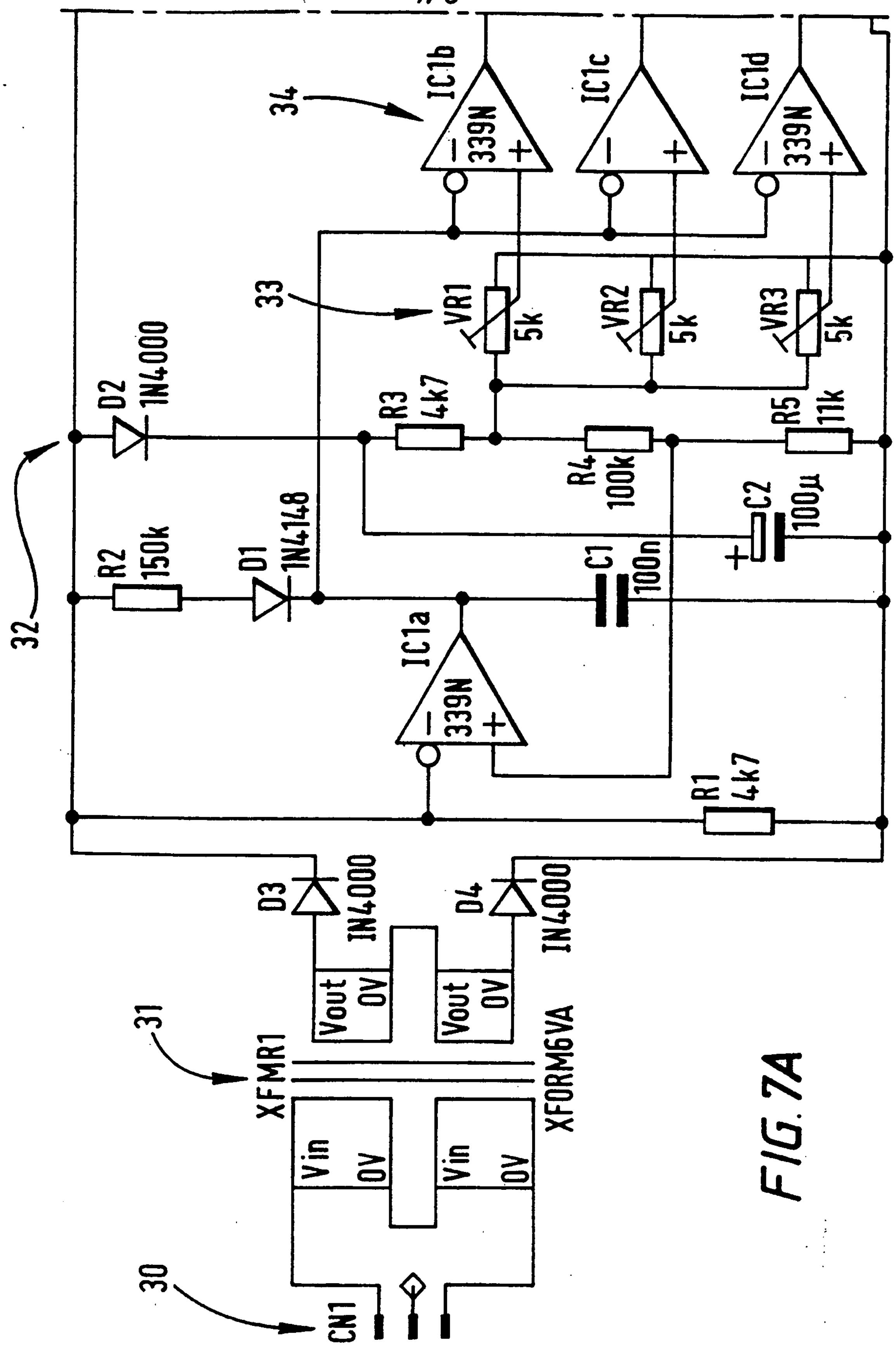
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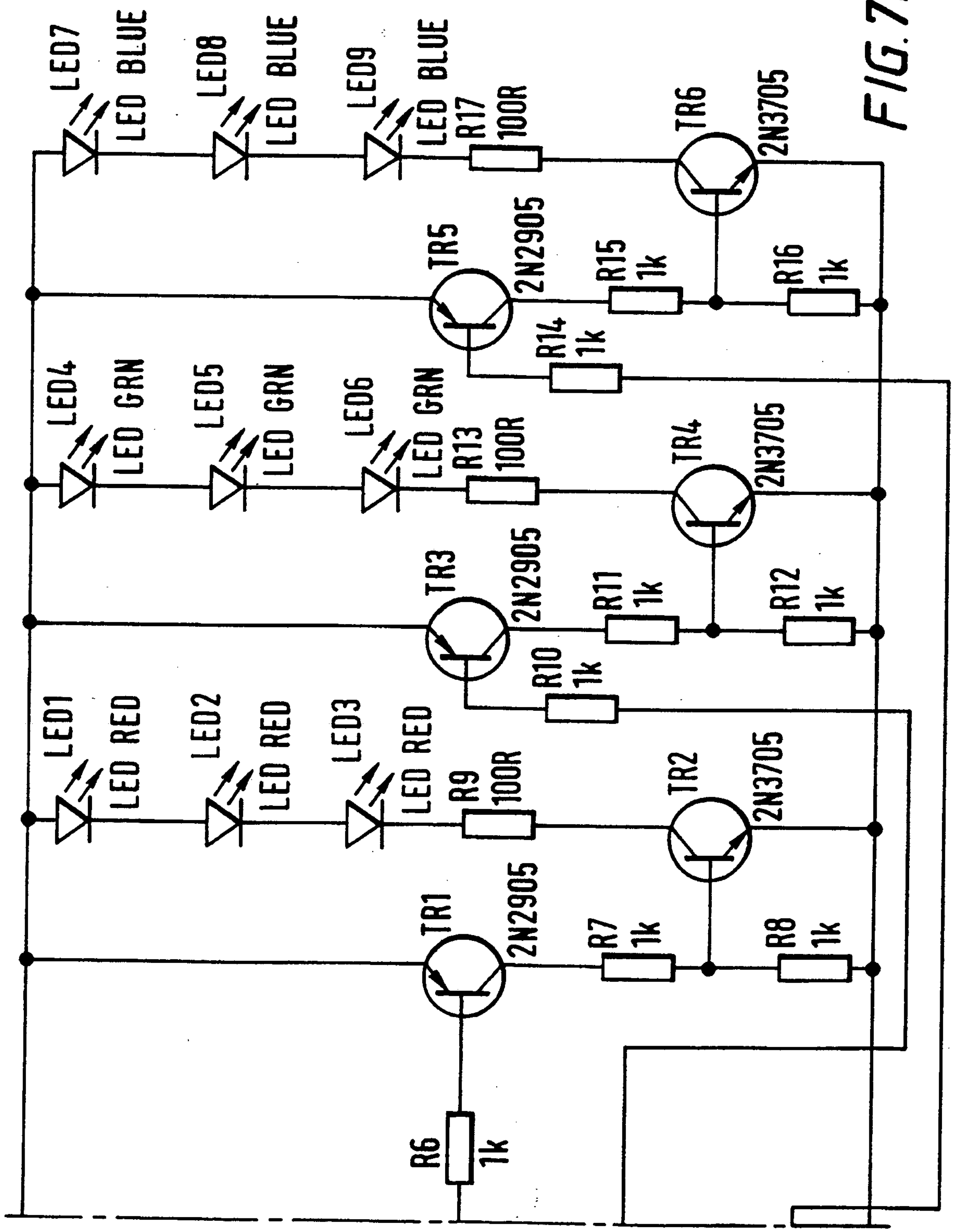
FIG. 7A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LED RED
R9
100R
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TR1
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R7
1k
R8
1k
R6
1k

FIG.7B

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 98/03729

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H05B33/08 H05B37/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	WO 97 48134 A (GENTEX CORP) 18 December 1997 see page 13, line 25 - page 48, line 8; figures 1-22	1,6-8, 12,15
A		2,3
X	WO 97 24706 A (CREE RESEARCH INC ;VEN ANTONY P VAN DE (US); SWOBODA CHARLES M (US) 10 July 1997 see page 16, line 7 - page 34, line 11; figures 1-12	1,6,7,12
A	DE 43 05 585 A (HELLA KG HUECK & CO) 25 August 1994 see figures 1-6	2,3

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[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
12 March 1999	18/03/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Albertsson, E

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 98/03729

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